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1 8. STRUCTURES TO CREATE AND MAINTAIN DIVERSE CHANNEL BEDFORM- [MODERATE]

- Create scour for rearing, holding and spawning (sorting and stability of bed material) habitat.
- Can induce scour by obstructing flow, constricting flow, or a combination of the two.
- These aren't necessarily just specific structures. Random placement of debris performs a valuable function in some situations.
- Supplement info on groins and barbs in ISPG, but clarify difference in objectives (protection vs. creation through scour).
- To create and maintain diverse bedform and thalweg.
- To encourage gravel deposition/stabilization/sorting.
- Include rock piles, groins, deflectors, digger log, debris jams (detailed elsewhere), vortex rock weirs, rock J-hooks, "V" log weirs, "unstructured" debris placement.

1.1 Introduction

1.1.1 Description of Technique

Scour is often viewed as an enemy by property owners and hydraulic engineers (and understandably so) for its role in undermining and flanking of structures. Scour is a natural process, however, that helps create and maintain a diverse channel bedform and thalweg. Such diversity is a key component of a productive stream habitat. Scour can produce a variety of depths, velocities, substrate types (substrate sorting), and cover that meet the needs of the various life stages of fish and other aquatic organisms.

Structures can be used to induce scour by three primary modes: flow obstruction and constriction, and plunging flow. Mid-channel objects such as boulders, bridge piers, and logjams generally present obstructions to flow. As shown in Figure 1, scour will typically produce a horseshoe-shaped pool along the upstream edges of such obstructions (a depositional bar will often trail downstream from the object). Bedrock outcroppings and bridge abutments that "squeeze" a channel are examples of flow constrictions. Scour pools are often found at, and immediately downstream of, such structures. Depositional bars are often found immediately downstream of these scour pools. Various weirs create plunging flow and its associated downstream plunge pool. These are typically log weirs, boulder weirs, or man-made weirs (typically concrete).

Commonly used scour structure configurations include rock piles, groins, deflectors, digger logs, debris jams, porous (rock vortex) weirs, rock J-hooks, various log weirs, "unstructured" debris placement, and boulder placement.

Many structures have the potential to serve as both a flow obstruction and constriction depending upon stream discharge level. The determination of whether obstruction or constriction is occurring is less important than the knowledge that any relatively immobile object placed in a mobile-bed channel will induce local scour and/or, if it produces a significant constriction in the channel cross-section, will induce constriction scour.

Depending on materials employed, scour-inducing structures may be a relatively short-term fix or a long-term fixture. For instance, unanchored woody debris may remain in place and induce scour only until a flood carries it away. An engineered barb or groin may last for decades or longer, resulting in semi-permanent associated scour holes.

1.1.2 Physical and Biological Effects

- *Scour and Deposition*. Inducing scour and associated deposition is the goal of scour structures. Often occurring in tandem, these processes provide variability in depth, velocity, and substrate size.
- *Channel Substrate Sorting and Retention*. The natural, seasonal occurrence of scour and deposition maintains pool depth and provides cleaning, sorting, and retention of gravels. Many aquatic species native to the Pacific Northwest rely upon this seasonal disturbance of bed materials to produce optimal habitat conditions.
- *Habitat Complexity At All Discharges*. Scour structures typically induce high velocity flow (and associated scour holes) along their upstream edges and produce a low velocity "shadow" immediately downstream. The pool created by scour, the depositional zone lying downstream of the scour structure, and the gradient in substrate size, depth, and velocity lying between them result in a high degree of habitat complexity near scour structures. If the scour structure is relatively large, the variability of conditions surrounding the structures will be maintained throughout a wide range of discharges.
- *Habitat Use At Different Seasons*. Salmonids are known to occupy different habitat types at different times of the year. While boulder weirs, deflectors and vanes may be heavily used during the summer, small salmonids prefer winter habitats associated with deep pools and complex LWD. Projects employing only boulder structures are less likely to meet the needs of salmonids year round.
- *Bed and Bank Erosion*. Scour structures are intended to produce bed erosion in the form of localized scour holes. Bank erosion may also occur for one of several reasons. Structures that cause channel constriction may result in bank erosion of one or both banks. This can occur if the constriction consists of a barb, groin, or similar structure(s) that protrudes from one stream bank. The more common method of erosion by these structures is caused to the bank they are attached to by the large eddy they create, particularly where has been cleared of natural vegetation (lawns, pastures, etc). Although less common, erosion of the far bank is possible if the structure blocks a significant portion of the channel through redirection or constriction of flows. Erosion of downstream banks is possible if the structures shift meander patterns.
- *Channel Backwatering*. Structures that cause a significant reduction in channel cross-

sectional area will cause backwatering. Effects of backwatering can include increased upstream water surface elevations and increased sediment deposition upstream of the structure(s). Projects along streams with FEMA regulatory 100-year floodplain boundaries cannot legally cause an increase in the 100-year water surface unless an application is made to adjust the regulatory flood limits. Increased upstream water surface elevations may, over time, result in adjustment of the elevation of streamside vegetation as lower-growing plants are drowned out. Increased sediment deposition upstream of scour structures can lead to problems if it is excessive. Excessive deposition can lead to habitat degradation through channel widening, associated bank erosion, and decreased channel depth. In extreme cases, excessive deposition may be accompanied by lateral channel migration. Such deposition is possible if the reduction in channel cross-sectional area produced by the scour structures is excessive. This condition is frequently seen upstream of under-sized culverts and bridges.

- *Habitat Value.* Scour structures can enhance fish spawning, rearing, holding, and cover habitat. As discussed above, scour structures produce a gradation of conditions ranging from pool to depositional bar in a relatively predictable pattern. The value of this habitat varies seasonally and according to the location of the scour structure. During high flows, adult fish may find holding habitat on the downstream side of mid-channel scour structures. Medium-range flows may find adult fish utilizing the scour pool as holding/feeding habitat. Gravels deposited downstream of the structure may be utilized for spawning. During low flows, adult and juvenile fish may utilize the scour pool located on the upstream side of the structure as rearing and low flow habitat. Structures constructed of wood or other porous materials will offer cover. Cover is also provided in the form of depth and turbulence in the scour zone. Structures constructed adjacent to the stream banks are likely to provide high flow refuge to adults and juveniles, in addition to the habitat opportunities mentioned above.

1.1.3 Application of Technique

- *Transport Reach vs. Depositional Reach.* Inducing and maintaining scour holes is generally easier along transport reaches than along depositional reaches. Along strongly depositional reaches, the reduced transport rate will tend to cause sediment to deposit and fill scour holes during the falling limb of a storm hydrograph, or subsequent low stream discharges. However, it is within minor to moderately depositional reaches (which tend towards shallow, broad channels with relatively low variation in thalweg elevation) that the benefits of successful scour structures may be most valuable.

  The tendency of a reach towards transport or deposition should be taken into account when designing scour structures. In particular, scour structures in depositional reaches should be designed to induce scour at the full range of expected discharges, including lower flows. This will help prevent the associated scour hole from filling with sediment at any point in the discharge range. Of course, the feasibility of maintaining scour holes at all should be evaluated. In some cases, the sediment load may overwhelm scour-inducing structures and render them ineffective.

- *Reaches where there is an identified physical or biological need.* Since scour structures can be very simple (e.g., a boulder) they are effective tools for enhancing habitat variability at the site and reach scale. Using scour structures, stream segments lacking bed variability can be enhanced with relatively little effort. Reaches that can benefit from scour structure installation include reaches with plain bed channel form (little variability in depth and substrate size) and areas characterized by mild to moderate deposition (excessive deposition may render the structure ineffective).

- *Alluvial channels.* Scour structures are very effective in alluvial channels with mobile bed materials. In alluvial channels that have undergone armoring that render the bed material effectively immobile (e.g., many urban channels), the scour hole may need to be excavated when the structure is installed.

- *Non-Alluvial channels.* Non-Alluvial channels commonly include colluvial headwater streams, bedrock-bed channels, and clay-bed channels. Scour structures may or may not be effective in colluvial channels, depending on the size gradation of the colluvial material and the ability of stream flow to mobilize it. Such channels are typically steep, and scour in these channels is often induced by drops created by boulders and logs (e.g., in step-pool type reaches). Such drops can be constructed using imported boulders and logs, although fish passage should be considered when constructing drops in a channel bed.

  Pools in bedrock-bounded systems are typically formed and maintained naturally, and need no intervention. Clay-bed streams often contain scour holes associated with woody debris and, if present, boulders. Such holes can be the primary mechanism of bed form variability in clay-bed streams. Scour structures can be an effective means to increase the habitat value of these streams.

- *Backwatered reaches vs. free flowing.* Scour structures are generally applied in free flowing reaches, and are usually ineffective in backwatered reaches. Backwatered areas are typically depositional, and scour effects are only likely to be present over a narrow range of discharges, if at all. Sediment mobilized at other discharge levels (typically smaller-sized sediment) will tend to fill scour holes in backwatered areas.

- *Stable vs. unstable or degraded stream reaches.* As with most habitat-enhancement strategies, scour structures are more likely to be initially effective, or remain effective, in stable reaches than in unstable reaches. Within unstable reaches or degraded reaches, the likelihood of successful scour structure implementation depends on the form of degradation or instability. As mentioned previously, reaches made unstable by excessive deposition are not promising sites for scour structures, as any scour induced by the structures is likely to be filled in with sediment. Scour structures are more likely to be effective in erosional reaches. In some cases, the localized deposition that often accompanies scour around these structures may actually aid in retaining sediment in such reaches. In highly disturbed sites scour structures may not be effective unless combined with channel re-construction or other channel restoration strategies. Scour structures should not be used as a substitute for recovering the riparian zone or addressing upland sediment sources.

- *For use in newly constructed or existing stream channels and side channels.* Scour structures are equally applicable to newly constructed and existing stream channels. Side channels are appropriate locations for scour structure installation providing the flows that they convey are capable of producing appreciable scour.

- *Limited by equipment access and reach.* Because scour structures are essentially immobile objects within the stream channel, they are typically constructed using large, heavy elements such as logs and boulders. The need for large, heavy elements may limit where scour structure construction is feasible.

- Rigid structures including log weirs, groins, and barbs require long-term monitoring and maintenance to ensure they do not become barriers to fish passage and that they function as designed. They also tend to "lock" the channel in place. For these reasons, they are not a preferred method for creating scour. Rigid structures won't lead to self-maintaining stream restoration—they are simply enhancement.

1.2 Scale

- *Small streams vs. large rivers.* Scour structures are appropriate for streams and rivers of any size. In large rivers, such structures usually consist of barbs, groins, or similar structures projecting from the riverbank. In such cases, the primary function of the structure is often bank protection. Scour structures in medium and small-sized streams may similarly consist of structures projecting from the bank (and producing local and/or constriction scour), but may also include mid-channel structures such as boulders, rock weirs, logjams, and channel-spanning objects such as logs.

- *Single vs. complex structures.* Scour structures may be as simple as a single boulder or rootwad or as complex as a series of large barbs. Size and complexity of structures depends upon a number of factors including stream size, site constraints, materials that are available and/or appropriate, and budget constraints. Because scour structures are very site-specific in their effects, habitat value associated with a single structure will be limited to that site. Complex structures are generally preferred to single logs or boulders because of the increased habitat benefits.

1.3 Risk and Uncertainty

- *Risk to public safety*. Since they obstruct and/or constrict flow, scour structures can pose a hazard to boaters and swimmers. In streams that are used for boating or recreational swimming, public safety issues should be carefully considered during the project assessment and design processes. Logs used in scour structures can contribute to culvert or bridge blockage during floods if they break loose from the structure, or if the structure becomes mobile as a unit. The risk of structural failure and potential downstream impacts should be considered during the project assessment and design processes.

- *Urban vs. non-urban.* Risks of structural failure are often amplified in the urban environment, where channels are typically constricted and culverts and bridges are relatively numerous. Hydraulic forces also tend to be more concentrated in constrained urban channels than in natural streams. Scour structures in urban streams should be designed with these factors in mind.

- *Risk to adjacent property*. Scour structures, particularly those that constrict the channel, can induce scour/erosion in adjacent streambanks. Additionally, structures such as barbs and groins may direct stream flow towards nearby streambanks (causing erosion at the point of flow impingement) or transfer bank erosion problems to a downstream location. In any of these cases, adjacent property may be subject to bank erosion.

- *Large vs. small streams.* Risk and consequences of failure are situation specific, but typically increase with stream size.

- *High gradient vs. low gradient stream reaches.* Scour occurs throughout a stream system, from headwater streams to major rivers. The relationship between gradient, substrate size, and scour potential makes scour structures a viable option for reaches of virtually all gradients. As with stream size, risk and consequences of scour structure failure are situation specific.

- *Confined vs. unconfined stream reaches* As with gradient, risk and consequences of scour structure failure are situation specific. Use of woody debris in confined reaches, however, generally requires more care than in unconfined reaches due to the higher potential for floatation and generally higher hydraulic forces.

- *Varies with the method.* Different methods carry different risks. For instance, woody debris can become mobilized and cause problems such as culvert blockage downstream. This risk is not present with boulders. Any method, however, carries the risk of causing bank erosion, etc, if improperly designed or constructed.

- *Uncertainty.* Scour involves complex hydraulic forces that vary with significantly at a site with varying discharge. The analysis and prediction of scour is an inexact science, and the best of methods and models cannot accurately predict the scour effects in natural settings with variable hydrology and sediment transport. Projects intended to create scour should be implemented with this uncertainty in mind.

- *What types of professionals need to be consulted?* The types of professionals involved in project design should reflect the size of the stream in question, the complexity of the design, and the possible consequences of design failure.

1.4 Data Collection and Assessment

- *Biological assessment of habitat needs in subject reach.* As with other habitat enhancement techniques, habitat needs in the subject reach should be addressed as part of the project planning phase. To assess whether scour structures might be helpful, general bed variability and sediment size (including spawning gravel availability) should be examined. In addition, availability of spawning, rearing, high flow refuge, and pool habitats should be quantified.

- *Hydrology and hydraulics.* To aid in structure design, reach hydrology and hydraulics should be analyzed using appropriate techniques from the Appendices (or equivalent methods). Scour associated with peak flows for a range of flood events should be considered. Often a more frequent, lower flow event produces greater scouring than a less frequent, higher flow event (e.g., due to backwater conditions during high flow). Hydraulic parameters needed for input to the various scour equations will be required for each flood considered.

- *Sediment, wood, and debris size and transport.* Sediment and debris transport rates and capabilities should be assessed in order to evaluate the appropriateness of scour structure construction on the project reach. This information is also used in selecting the scour structure type, selecting materials, and meeting stability requirements for the structure. Placeholder: discuss thresholds that would make the technique inappropriate

- *Geomorphic Assessment, Watershed Processes, and History.* An assessment of stream geomorphology, watershed processes, and history should be carried out to evaluate the appropriateness of scour structure construction on the project reach, and its likely effects on adjacent stream reaches and on the system as a whole. Disturbances within the basin should be considered to qualitatively understand the pre-project stability of the stream. A watershed with no significant disturbances in the preceding decades suggests a dynamically stable system. Natural occurrences of woody debris and boulders that have induced scour could therefore be used as analogs to estimate extent of scouring or induced sediment deposition. Watersheds that have been disturbed significantly in recent history should be assessed for changes to hydrologic regime, sediment inputs, sediment conveyance and hydraulic conditions. Land use changes such as urbanization can change the timing, volume and peak discharge of return period floods. Increased energy can lead to unstable channel conditions. Modifications to the channel and flood plain can alter hydraulic conditions and therefore sediment transport conditions. Recent increases in sediment delivery into a stream (e.g. landslides, increased channel bank erosion) may not be apparent along downstream reaches, and naturally occurring scour features along downstream reaches may provide a false indication of stable channel scouring conditions.

1.5 Methods and Design

All stream enhancement design should consider natural channel processes. Processes particularly important to scour structure design include sediment transport characteristics, such as deposition and erosion rates, and natural bed form characteristics, such as pool frequency and location. As mentioned previously, sediment transport characteristics govern structure effectiveness in terms of scour pool development and maintenance, depositional bar formation, and substrate size and sorting. In order to be effective in the short and long term, scour structures should work in concert with these natural channel processes.

1.5.1 Design Components Common to all Scour Structures

Placeholder: Design discussion needs a set of paragraphs that generally discuss the design methods, models and analyses that can be applied to design scour. This can refer liberally to appendices (Hydrology, Hydraulics, Sed Trans, etc.) and other documents as necessary, but at a minimum should describe the basic design components that are common to all the various scour structures – i.e. hydrology variable, hydraulic model, depth of scour, how to protect against undermining. Describe how each of these is considered, and where readers can get needed additional information and guidance on methods.

1.5.1.1 Hydrology

Placeholder – brief discussion of hydrology as a design component

The planning and design processes should include determination of the range of flows at which the structure is intended to induce scour. Some structures (e.g., vortex weirs and J-hooks) are relatively low in profile and induce scour most effectively at low or medium range flows. Higher structures may exert their influence primarily at medium or high flows. A structure of varied height may induce scour effectively at the full range of flows.

1.5.1.2 Evaluating Hydraulics

Placeholder – brief discussion of hydraulics as a design component – what aspects of hydraulics to consider and how to analyze

The degree that a structure intrudes into the channel, or blocks the central channel area, must be determined based on site conditions and project goals. Put simply, structures that obstruct and/or constrict channel flow significantly tend to exert a high influence on channel hydraulics. Structures that lie low in profile and/or do not significantly obstruct or constrict the channel cross-section will exert a lower influence on channel hydraulics.

Hydraulic design in a natural environment, using natural materials, involves a significant degree of uncertainty. Equations and methods presented in the Hydraulic Appendix are useful in the analysis and design of scour structures. These tools must be employed with an understanding of natural stream systems and sound professional judgment.

1.5.1.3 Depth of Scour

Placeholder – brief discussion of depth of scour as a design component and how to predict or use as a design tool

1.5.1.4 Sediment Transport

Placeholder – brief discussion of sediment transport as a design component and how to predict or use as a design tool, discuss depositional vs. transport reach and how this affects design. This can be moved from or paraphrased from elsewhere in this document where this is already addressed.

1.5.1.5 Protection Against Undermining

Placeholder – brief discussion of how to protect structure against being undermined as a design component

1.5.1.6 Location and Spacing of Scour Structures

Bed form characteristics such as pool frequency and location can be determined from a reference stream reach and will be essential to determining appropriate spacing, frequency, and locations of scour structures. Refer to the Geomorphology Appendix for further discussion on the use of reference reach approaches to design.

In general, scour structures should be located within the active channel. It is here that the structures, and the habitat that they create, will be useful over the broadest possible range of flows.

1.5.1.7 Design Considerations for Rock Structures

Present all design considerations for use of rock – size of rock, kind of rock, etc. Refer to Boulders Technique, and make sure that both have consistent info, or that one refers to other technique.

Boulders should be sized so as to remain immobile at the design discharge (typically the 10-yr discharge, or greater). Boulders placed on fine-grained streambeds are likely to “sink” into the bed as scour removes material around their bases. A stone foundation extending below the depth of scour can prevent such undermining. However, locations in which such undermining is likely should be scrutinized, as boulder placement in such streams may be inappropriate.

1.5.1.8 Design Considerations for Log Structures

Present design considerations for use of logs, and refer readers to other Techniques that cover this in greater detail – Debris Jam technique, Log Cover technique, and Integrated Streambank Protection Guidelines where anchoring is detailed.

Disadvantages of using logs for structures include their eventual decomposition and the common requirement for anchoring log ends into streambanks using rock. Use of redwood or cedar logs can greatly increase the effective life of a weir. Use of hardwoods like alder or cottonwood is discouraged, as their decomposition rates can be relatively high.

Log and wood debris strucutures can provided significant additional value in the form of cover and complex pool habitat. Generally, wood complexes provide greater value than single logs and tend to be more stable. For further detail on stability, habitat value, and design components and considerations for log structures, refer to Debris Jam and Log Cover techniques, and to the Integrated Streambank Protection Guidelines Anchoring Appendix.

1.5.2 Design Considerations for Specific Scour Structures

The *Washington Integrated Streambank Protection Guidelines* includes discussion of rock piles, groins, deflectors, digger log, and porous weirs and their application to protecting streambanks from erosion, including the advantages and disadvantages of each of the methods and under what site conditions they might best apply.

1.5.2.1 J-hook Vanes

J-hook vanes are low profile, barb-like structures popularized by Dave Rosgen. They are basically a double row of boulders angled upstream with a “hook” at the end that focuses flow through a pocket (Figure 2). They may also be constructed with logs for the angled section and boulders for the “hook”. Scour occurs in the pocket of the “hook” and, to some extent, along the downstream edge of the entire structure. Rock J-hooks are appropriate on small to medium-sized streams where boulders naturally occur. They are not particularly appropriate on rivers, streams with morphology dominated by large woody debris, or streams with fine-grained bed materials. Log vanes may be more appropriate in those situations.

Rock J-hooks should be installed with a relatively low profile, such that the tops of the boulders are exposed at low to average flows but submerged by higher flows. Current recommendations begin with the straight "leg" of the structure angled 20-30 degrees from the upstream bank. The crest of the leg slopes down at 3-7% from bankfull elevation at the bank, to design bankfull depth at the hook. The leg should extend out to 1/3 of bankfull width, and the hook crosses the second third of channel bankfull width. The hook will then be located far enough from the streambank so the scour pocket will not undermine the bank. If built to these guidelines the vane will frequently occupy the entire low flow channel width. (Provide references.)

Logs with intact rootwads may be incorporated in J-hook vanes to provide additional cover in the plunge pool. They are anchored by placing them beneath the top row of boulders with the bole buried in the upstream bed and the rootwad in the plunge pool. Additional boulders may be placed on the bole if necessary. Logs should be placed in the leg of the vane, and the rootwad is either mostly or completely submerged.

The structure should be keyed into the bank a sufficient length to prevent flanking. For small J-hooks this distance may be as little as 5 feet. Key length for larger structures should be determined based on the barb design recommendations provided in *Washington Integrated Streambank Protection Guidelines*.

1.5.2.2 Log Weirs

Log weirs are used to provide abrupt drops in channel bed elevation that induce scour pool formation and, often, associated gravel sorting and retention. It is important that the weirs not create a jump height of more than 12 inches, or they may become a barrier for up-migrating adult trout (the jump height should be less than 6 inches where juvenile up-migration is desired). A variety of log weir configurations have been used, including V-logs, level and perpendicular logs, angled and sloped logs, and K-dams.

"V" log weirs are appropriate for use in relatively small streams were large woody debris naturally occurs. Stream gradient should be relatively steep. California Department of Fish and Game (1998) recommends using log weirs on streams with gradients from 1.5 to 4 percent. .

"V" log weirs that span the channel are configured such that, viewed from above, the point of the "V" is oriented upstream (Figure 3). This configuration focuses stream flow towards the center of the channel as it plunges over the log crests, maximizing scour. Log ends should be keyed into the streambanks at least 6 feet and stabilized with rock as necessary to prevent flanking (California Department of Fish and Game, 1998). As shown in Figure 3, a sill log spanning the channel perpendicular to flow can be used as a base for the "V" logs (California Department of Fish and Game, 1998). Another variation is to skew the point of the "V" closer to one bank if developing a thalweg closer to one bank is preferred.

Variations of the "V" log technique that provide flow constriction are shown in Figure 4. The objective in this case is to force stream flow between opposing deflectors. The downstream ends of the deflectors should always be oriented as shown in Figure 4 so that overtopping flows will be directed towards the center of the channel. When a bedrock bank or very large boulder is present, a single log deflector can be used to "squeeze" flow against the boulder and create a constriction.

Full span log weirs can be constructed at various angles to the streamlines and at various slopes relative to the streambed. This design is appropriate where some degree of bank scour is acceptable or preferred. The more acute log angles will require longer logs in order to span the channel and have adequate burial into the banks. The greater the slope of the log crest, the greater concentration of flows against one bank with more erosive power focused on that bank. Weirs with sloped crests, like V-logs, provide a concentrated jet of flow even as flows recede. This can be a benefit to fish migration, particularly at low flows.

Perpendicular log weirs have been used extensively by WDFW in correcting fish passage barriers at dams and culverts. A series of log weirs are used to raise bed and water surface elevations in order to backwater culverts or reduce the jumping height at small dams. Making the weir crest level helps keep the entire log wet and thus prevent decay. The bed that deposits on the upstream side of the weir is usually flat, which may or may not be desirable. Perpendicular log weirs tend to widen alluvial channels and scour the bank at each end of the log. This requires bank armoring at each end to maintain the structural integrity of the weir. Perpendicular log weirs with 1-ft drops in gravel bed streams typically develop plunge pools that are 2-2.5 ft deep.

K-dams are more complicated log weirs that are shaped like the letter "K" in plan view. They have been installed throughout the country, but have not been widely used in Washington State.

1.5.2.3 "Unstructured" Debris Placement

Unstructured debris placement describes the placement of large woody debris in such a manner that it acts as a scour structure. "Unstructured" debris placement includes logs and rootwads placed singly or in small groups. Larger, more complicated woody debris structures (commonly called "engineered log jams") are discussed at length elsewhere in this document.

Typically, woody debris is placed in locations that mimic natural collection points for debris to promote natural process and dynamic stability. In steeper streams in forested areas, large woody debris often plays a dominant role in channel morphology (Keller and Swanson, 1979). In such streams, scour and associated pools are often associated with woody debris. On a fifth order stream in the Oregon Cascades, Nakamura and Swanson (1994) found that wood most commonly collected naturally at the entrance to (and within) secondary channels, along the outside of bends, and behind or between large boulders. Abbe and Montgomery (1996) found log jams to naturally occur most commonly at the upstream end of gravel bars and mid-bar, atop the bar surfaces on the Queets River, a relatively large river draining the western portion of Mount Olympus, Washington.

Robison and Beschta (1990) studied large woody debris distribution and orientation in coastal streams in Alaska. They found that 80% of the woody debris associated with 1st (and some 2nd) order streams was suspended above (spanning) or lying outside the bankfull channel. In 4th order streams, 60% of the wood observed lay within the bankfull channel area. Approximately 1/3 of all woody debris was oriented perpendicular to the channel, regardless of stream order.

Based on these studies, and on the need for scour structures to be within the active channel, recommendations for "unstructured" debris placement include:

<u>Smaller streams (width range?)</u>: Digger logs that span the channel or intrude into the channel can be used to induce scour pool formation. Digger logs are full or partial span logs that are elevated some distance off the streambed. Part or most of the flow is forced below the log, scouring out a pool. Sill logs (weirs) that lie within the channel can be used to form/maintain plunge pools.

<u>Medium-sized streams (width range?)</u>: Woody debris should lie within the active channel, or intrude into it significantly. Logs that span the stream may be applicable depending on site constraints. Locations at the outside of bends and the head of natural gravel bars tend to be relatively stable. The outside of bends, in particular, provides an environment where scour is likely to occur predictably throughout a range of flows.

<u>Large streams and rivers (width range?)</u>: Woody debris should lie within the active channel, or intrude into it significantly. As with medium-sized streams, locations at the outside of bends and the head of natural gravel bars tend to be relatively stable, and the outside of bends provide an environment where scour is likely to occur predictably throughout a range of flows. Anchoring of woody debris becomes a bigger concern on larger streams and rivers. Anchoring of woody debris is covered at length in the *Washington Integrated Streambank Protection Guidelines*.

1.5.2.4 <u>Boulder Placement</u>

Boulder placement, for the purposes of this text, is considered the installation of boulders singly or in clusters to induce scour (and associated gravel sorting, etc). Boulder placement is appropriate on alluvial streams where boulders naturally occur. Boulder placement is not always appropriate on streams with morphology dominated by large woody debris, or streams with fine-grained bed materials.

Used singly, boulders tend to induce scour hole formation immediately upstream and deposition immediately downstream. Clusters of boulders can, as a unit, accentuate these effects. Better habitat is developed when LWD is added or attached to boulder clusters (Ward and Slaney, 1979)

Boulders should be sized so as to remain immobile at the design discharge (typically the 10-yr discharge, or greater). Boulders placed on fine-grained streambeds are likely to "sink" into the bed as scour removes material around their bases. Locations in which such undermining is likely should be scrutinized, as boulder placement in such streams may be inappropriate.

More guidance is provided in the Boulder technique.

1.5.3 Materials

Most scour structures can be constructed wholly, or in large part, of naturally occurring materials such as wood and stone. Commonly used non-natural anchoring materials include cable, chain, concrete blocks and articulating metal plate earth anchors (e.g. Duckbill anchors, Manta ray anchors). Barbs, groins, and similar structures intended primarily as bank protection, and functioning secondarily as scour structures, may contain non-natural materials such as concrete armor units. While these structures provide bank protection and secondarily promote scouring, they do not promote process. Therefore, in general, the designer should strive to promote natural process and the associated dynamic stability through the use of natural materials as much as possible, and to use materials appropriate to the location and stream type.

1.6 Project Implementation

1.6.1 Permitting

Refer to Chapter section 4.6 for a comprehensive discussion of permitting

1.6.2 Construction

Concerns involved in scour structure construction mirror the general considerations discussed elsewhere in this document. Scour structures are generally constructed of large, heavy materials, and the delivery and installment of these materials can limit the location of scour structure construction.

1.6.3 Cost Estimation

Three types of barbs were installed on the Nooksack River in 1998 in a project intended to both create scour for habitat value and protect river banks. Although the barbs were installed to halt bank erosion, they serve a secondary role as scour structures (Figure 5). The installation costs for the three barb types were as follows:

Rock barbs, 100 ft long (including key), 4 ft minus rock: $X/barb
Rock/dolo barbs, 100 ft long (including all-rock key), 4 ft minus rock: $X/barb
Pile/log barbs, 50 ft long (including key) $X/barb

Rock and wood cost and availability can vary. Rock cost, in particular, can vary according to local size and quantity availability. In general, rock cost can range from approximately $X-Y depending on location. Very large rock is not always locally available, and long distance hauling will increase rock cost significantly.

Wood cost varies widely according to species, size, and locale. In some cases, wood of low commercial value can be obtained for the price of hauling it away from sites that are being cleared for development. On the other end of the spectrum, mature red cedar may cost thousands of dollars per log. Transporting logs with intact rootwads may be challenging because of road hazards created by dislodged soil or rocks and roots overhanging into adjacent travel lanes. A solution is to switch from logging trucks to lowboy trailers or various styles of dump trucks, particularly those with extended beds.

Similarly equipment/installation costs can vary widely by locale. For example, excavator and operator rates can vary from approximately $X/hour in the Seattle area to $X/hour in northeast Washington. Local rates can generally be estimated based on conversation with a few local contractors. The circumstances and location of the work can effect project installation cost as much, or more, than locale. When working in difficult-to-access sites and/or space-constrained conditions, construction crews and equipment may require twice (or more) as much time as they would to complete tasks under ideal conditions.

1.6.4 Monitoring and Tracking

Monitoring of scour structures should answer the questions: "did the structure stay in place or remain structurally sound?"; did the treatment affect overall fish production in the system?; does the structure provide favorable fish habitat (what fish, season, and age class)? To answer these questions, monitoring may include any or all of the following elements:

- Section and Profile Data;
- Bed Substrate Data;
- Photo Points;
- Snorkeling/Utilization surveys;
- Wood tagging;
- Habitat mapping/quantification; and
- Spawning Surveys

1.6.5 Contracting Considerations

Contracting considerations are discussed in the Construction Appendix.

1.7 Operations and Maintenance

Scour structures are designed to function through the natural processes of scour and deposition, and should require no maintenance. Structures with a primary purpose other than to induce scour, for instance barbs and groins, may require periodic maintenance and repair. See the *Washington Integrated Streambank Protection Guidelines* for operation and maintenance for barbs, groins, and other bank protection structures.

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1.8 Examples

Barbs installed on the Nooksack River are an example of scour structures. Although the barbs were installed primarily to provide bank protection, they have induced scour near their tips (Figure 5). These scour holes have been measured at up to X feet deeper than the surrounding streambed.

Wood placement on Klahowya Creek has maintained the thalweg of a perched, previously aggrading channel.

1.9 References

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1.10 Photo and Drawing File Names

Scour Drawing 4
Scour Drawing 3
Scour Drawing 2
Scour Drawing 1
Scour Photo 1

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